June 1, 1937. J. S. PARKINSON 2,081,952

ACOUSTICAL CONSTRUCTION

Filed Dec. 17, 1934

Fig. 1.

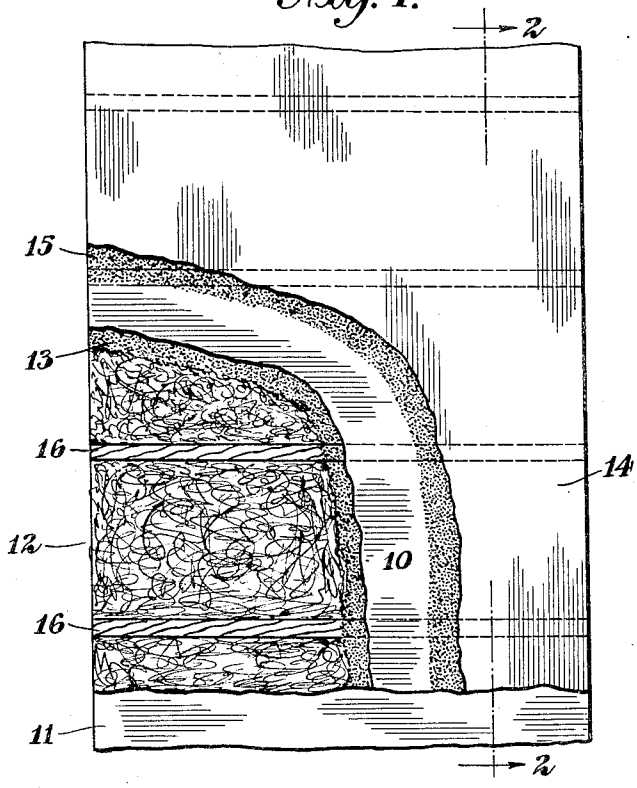


Fig. 2.

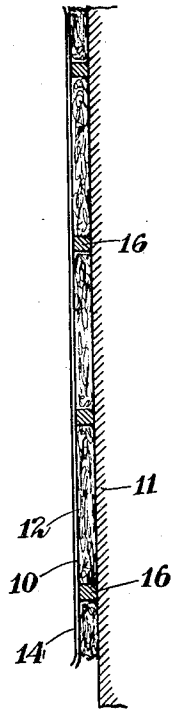
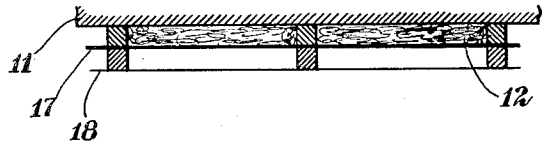


Fig. 3.



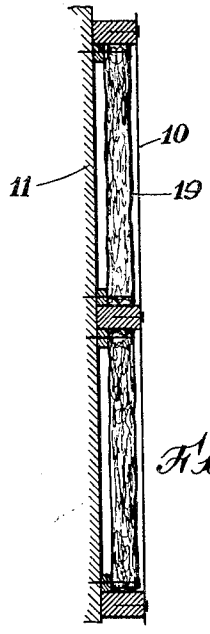


Fig. 4.

INVENTOR.
John S. Parkinson.
BY D. N. Halstead.
ATTORNEY.

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ACOUSTICAL CONSTRUCTION

John S. Parkinson, Somerville, N. J., assignor to Johns-Manville Corporation, New York, N. Y., a corporation of New York

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11 Claims. (Cl. 154—44)

This invention relates to an acoustical structure and particularly to one adapted to absorb sound of low frequency.

The structure is useful, for example, in automobile bodies, especially in certain of the newer types having relatively large expanses of plane or only slightly arched sheet metal. Such bodies frequently develop a rumbling sound of frequency largely in the range of 200 to 500 complete cycles per second.

It is customary to absorb sound in layers of felted fibres, porous ceramic materials or other elements having small intercommunicating voids or passageways. When it is desired to conceal the sound-absorbing member, there is sometimes applied a facing element. Thus, there has been used perforated metal, cloth, or like material adapted to permit the passage of sound through apertures or perforations therein. Also, there has been proposed the use of continuous non-apertured elastic facing membranes, such as taut doped fabrics or thin sheets of elastic metal, such as steel.

In some constructions there is objection to the use of apertured facing members and, also, to the use of membranes that, when struck, may emit a drum-like or tinny sound.

I have now found that sound may be absorbed by allowing the sound to impinge upon a structure including, as a facing member, an inelastic vibratile sheet such as a thin rag felt impregnated or coated with asphalt which may include a backing of sound-absorbing material, as, for example, a layer of hair felt.

Briefly stated, one embodiment of the invention comprises an acoustical structure comprising in combination a facing member, exposed on its forward surface to incident sound, including a substantially inelastic vibratile membrane and a sound-absorbing element disposed behind the said membrane. The invention comprises also an acoustical structure in which the membrane exposed to the sound to be absorbed is of predetermined mass, the mass being relatively large when the sound to be absorbed is of low frequency, relatively small when the sound to be absorbed is of high frequency, and intermediate in magnitude for sound of intermediate frequency or pitch. Another feature of the invention is the combination of a plurality of vibratile membranes spaced one from another and of differing masses, the lightest or lighter of the membranes being the one which the sound to be absorbed strikes first and the heaviest or heavier being the membrane which the sound strikes last. Another feature is the correlation of the frequency of the sound to be absorbed and the mass and spacing of the membrane from a wall or the like. Other features and advantages of the invention will appear from the detailed description that follows.

A preferred embodiment of the invention is illustrated in the attached drawing and will be described in connection therewith.

In the drawing

Fig. 1 shows a plan view of an assembly constructed in accordance with the invention, with parts broken away for clearness of illustration;

Fig. 2 shows a sectional view on line 2—2 of Fig. 1;

Fig. 3 shows a sectional view of a modification of the invention; and

Fig. 4 shows a sectional view of another modification.

In the various figures like reference characters denote like parts.

There are shown a facing membrane 10, a rigid sound-impermeable member 11 constituting the back of the structure and being a base member of the type of a wall or sheet metal such as used in the body of an automobile, a space defined between the elements 10 and 11, and a sound-absorbing element 12 disposed within the said space. As illustrated in Fig. 4, the sound-absorbing element 12 may be spaced somewhat from both the membrane 10 and the rigid member 11.

Or as shown in Figs. 1 and 2, the membrane 10 may be adhered on one side to the sound-absorbing element 12, as by means of the adhesive 13 of asphalt or other suitable material. Likewise, the membrane 10 may be adhered on its other or forward side to the finishing fabric 14 of silk or the like, as by means of adhesive 15 which may be of the same type as the adhesive 13. The membrane 10, either alone or adhered to the cement 13 or 15 and/or to the fabric 14, if used, may be considered as a membrane exposed on its forward surface to the sound to be absorbed.

The furring strips 16 provide means for supporting the membrane in spaced relationship to the wall or rigid member 11.

The structure shown in Fig. 3 is adapted to absorb sounds of a wide range of frequencies. In this modification, there is formed a combination of the rigid member 11 and a plurality of membranes of differing masses, such as the elements 17 and 18. In such an assembly the membrane of lightest mass is best placed on the out-

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side, that is, exposed in the direction of incidence of the sound to be absorbed and the heaviest or heavier membrane is the one nearest to the member 11. The sound to be absorbed impinges first upon the former membrane and last upon the latter. The former membrane absorbs preferentially the sound of high frequency, the sound of lower frequency being transmitted for absorption by the rearwardly disposed heavier membrane.

The facing members, including the membranes 10, 17, and 18, are suitably flexible, air-impermeable, vibratile sheets or membranes. The term "vibratile" is here used to mean capable of displacement, alternately forwardly and backwardly under the influence of sound waves. In general, the membranes disclosed are formed of a material which will enable them to be resonant over a wide range of vibration frequencies instead of being sharply resonant over a narrow range of vibration frequencies. The applicant's facing members of preferred type have sufficient internal resistance to relatively rapidly damp out free vibrations resulting from an initial displacement.

A membrane that has been used with satisfaction is one containing a rag felt such as used as a base for roofing paper and in the condition of having been continuously coated externally or impregnated with asphalt or the like in amount sufficient to render the felt substantially air-impermeable. The term "air-impermeable" as applied to a material is used herein to mean that the material is impermeable to air to such a degree that air-borne sound does not pass readily or to a substantial extent through the material but causes the material to vibrate appreciably upon impingement of the sound wave thereupon. Thus there has been used an asphalt-impregnated paper containing asphalt in proportion of the order of 50 to 60 percent of the total quantity that might be introduced at complete saturation. The asphalt used as the impregnating material may have, for example, a specific gravity of the order of 1.04 at 60° F., and a melting point above 100° F., by the ball and ring test method of the American Society for Testing Materials. A suitable proportion of impregnating asphalt is about 100 to 130 parts for each 100 parts of non-impregnated felted fibrous base material. The impregnated felt, as supplied for being assembled into the structure, may have adhered to one or both faces thereof a cementing layer, as, for example, an asphaltic composition adapted to be softened by the application of solvent, just preceding the adhering of the felt to another element in the assembly. The finished felt may have a weight of about 0.32 to 0.38 pounds to the square foot and a thickness of about 0.060 to 0.075 inch, after the application to a face thereof of a cementing layer, as described.

As stated, the facing member may have a mass that is predetermined in advance, to adapt the structure to absorb sound of a given frequency. Thus, the mass should be relatively large when the sound to be absorbed is of low frequency and the mass should be relatively small when the sound to be absorbed is of high frequency. For a given spacing of the member 10 from the member 11, the said mass should be inversely proportional approximately to the square of the frequency of the sound to be absorbed. For a spacing of three-fourths inch between the membrane and member 11, it has been found that a membrane having a mass of approximately 22 grams to the square foot is suitable when the sound to be absorbed is of a frequency of the order of 1000 cycles. Under the same conditions, the mass of the membrane may be around 230 grams per square foot for sound of a frequency of 300 cycles.

For intermediate frequencies of sound between 300 and 1,000 cycles the mass of membrane should be between 22 and 230 grams to the square foot. Also, for sound of 1,000 cycles frequency, the product of the spacing, expressed in inches, of the membrane from the member 11 and the mass of the membrane in grams to the square foot is preferably of the order of $\frac{3}{4}\times 22$ or about 16, whereas for sound of 300 cycles frequency the product of the spacing by the mass, as expressed above, should be of the order of $\frac{3}{4}\times 230$ or about 172.

The membranes 18 and 17, respectively, may have about the masses stated, provided the sound to be absorbed contains substantial proportions of sounds of high and low frequencies, say, largely, in the range from 1000 to 300 cycles. The membrane of mass of 22 grams would be in front of the other. A layer of sound-absorbing material 12 may be disposed behind at least one of the membranes 17 and 18.

The membranes should lie in planes generally transverse to the direction of incidence of the sound to be absorbed.

The finishing fabric 14, such as the silk lining of the interior of an automobile body, the adhesives or cements 13 and 15, and, in general, the mass, that is effective from the standpoint of vibration, of any element adhered to the membrane 10 is to be considered as a part of the mass of the facing member.

When the sound-absorbing element 12 is a yieldable material of the type of hair felt and is disposed directly in contact with the membrane 10 or adhered thereto, the element 12 serves not only to absorb sound but also to damp vibrations of the element 10.

Details of a typical commercial acoustical structure made as described are given below.

Against a substantially rigid metal sheet there were placed furring strips three-fourths inch thick dividing the area of the sheet into portions 1.33×4 feet. Over these portions there were placed sound-absorbing pads of hair felt containing a substantial proportion of asbestos fibres. A felt that was used weighed 0.6 pound to the square foot in a thickness of three-fourths inch. A sound-impermeable membrane consisting of a thin sheet of incompletely saturated asphalt felt, of the type described, was disposed over the three-fourths inch felt, on the side thereof remote from the member 11. With the membrane adhered to the sound-absorbing element or felt, the sound-absorption of the structure, for sound in the range of frequency of 250 to 500 cycles, was above 47 per cent for all frequencies tested, with substantially higher percentages of sound-absorption at certain frequencies.

In the structure of the type shown in Fig. 4, the sound-absorbing element 19 may be rigid or yieldable. In this structure there is a space of predetermined thickness between the membrane 10 and the wall or rigid member 11. The thickness of this space has a bearing upon the thickness of the sound-absorbing element 19.

The mass of the membrane and, distance of preferred spacing from member 11 are approximately inversely proportional to each other, for sound of a given frequency. Thus for sound of

frequency 1000, a membrane of mass of 22 grams to the square foot may be spaced three-fourths inch from member 11; a membrane of mass 72 grams may be spaced only one-fourth inch. Likewise, for sound of 500 cycles frequency, the comparable data are approximately as follows: 88 grams and three-fourths inch, and 22 grams and three inches.

When factors not stated, such as the percentage of the sound absorbed, are constant and when the sound to be absorbed is of a given frequency (f), I may use a predetermined mass (m) and spacing of the facing member from the rigid member 11, that is, the distance (s) between the forward surface of the facing member and the forward portion of the rigid member 11, such that $f(sm)^{1/2}$ equals approximately a constant. When f is expressed in complete cycles per second, s in inches, and m in ounces, I have found the said constant for a desirable set of conditions to be about 780. This relationship holds closely for a considerable range of materials and for a wide band of frequencies, because other factors such as stiffness are relatively unimportant within this range. There is, however, a slight variation from the simple relationship. A more accurate expression relating mass to frequency in my structures, at a spacing of three-fourths inch is $.531 \log m = 2.96 - \log f$. As sounds are usually composed of a number of different frequencies, sound treatments should be designed so as to be effective over a considerable range of frequencies, such as the range heretofore set forth. It will be understood, therefore, that the frequencies (f) mentioned in the foregoing discussion and formulae will generally be selected so as to be substantially the mean frequency of the range over which the sound treatment is to be effective.

There have been presented above certain mathematical relationships between frequency of the sound to be absorbed, the mass of the facing member and the spacing thereof from the rigid member or wall 11. These relationships are those that have been found by me, as the result of extensive research and testing, to give the best results in sound-absorption, when other conditions are kept constant. Thus, I have kept constant factors other than the mass of the membrane and have determined by the standard reverberation method the absorption of sounds of selected frequencies for various selected masses of the membrane. Likewise, I have varied the spacings of membranes of different mass from the wall 11 and have observed that, for best results with sound of a given frequency, the product of the distance of spacing and the mass of the membrane should be approximately a constant. Likewise, I have determined that better results in sound-absorption are obtained when the mass of the membrane in my construction decreases, within the limits stated, with increase in the frequency of the sound to be absorbed.

While the invention is not limited to any theory of explanation of the interesting results obtained, it is believed that the high internal friction of a material such as the partially saturated rag felt is a factor in the absorption of energy, as the membrane is caused to move to and fro under the influence of the incident sound.

The above description and specific examples are to be taken as illustrative only. Any variation or departure therefrom which conforms to the spirit of the invention is intended to be included within the scope of the claims.

What I claim is:

1. A sound-absorbing structure comprising in combination a substantially air-impermeable facing member including a thin sheet of asphalt-impregnated felt exposed on its forward surface to the sound to be absorbed, and a sound-absorbing element disposed behind and adjacent to the said facing member.

2. A structure adapted to absorb sound of a given frequency comprising a rigid, substantially air-impermeable member of the type of a wall and a facing member of predetermined mass spaced from the said rigid member at a predetermined distance, the frequency (f), the said mass (m), and the said distance (s) being related to each other in manner such that $f(sm)^{1/2}$ is approximately a numerical constant, when all factors not stated are constant.

3. A sound-absorbing structure comprising in combination a substantially rigid backing member, a flexible, substantially air-impermeable, vibratile membrane, resonant over a wide range of frequencies and exposed on its forward surface to the sound to be absorbed, and a sound-absorbing element disposed behind and adjacent to the said membrane, the product of the spacing in inches of the said membrane from the said backing member multiplied by the mass in grams to the square foot of the said membrane being about 16 when the sound to be absorbed is of the order of 1,000 cycles frequency and the product of the spacing and mass of the membrane, similarly expressed, being about 172 when the sound to be absorbed is of frequency of the order of 300 cycles.

4. A sound-absorbing structure comprising a rigid member constituting the back of the assembly and a vibratile facing membrane exposed on its forward surface to the sound to be absorbed, spaced from the said rigid member at a predetermined distance, and being of predetermined mass, the said mass being approximately 22 grams to the square foot when the sound to be absorbed is of frequency of the order of 1,000 cycles, approximately 230 grams to the square foot when the sound to be absorbed is of frequency of the order of 300 cycles, and between 22 and 230 grams when the sound to be absorbed is of frequency between 300 and 1,000 cycles.

5. A sound-absorbing structure comprising a rigid member constituting the back of the assembly, a vibratile facing membrane exposed on its forward surface to the sound to be absorbed and spaced from the said rigid member at a distance of the order of three-fourths inch, and a porous sound-absorbing member disposed between the rigid backing member and membrane, the mass of the membrane being approximately 22 grams to the square foot when the sound to be absorbed is of frequency of the order of 1,000 cycles, approximately 230 grams when the sound to be absorbed is of frequency between 300 and 1,000 cycles, and between 22 and 230 grams when the sound to be absorbed is of frequency between 300 and 1,000 cycles.

6. A sound absorbing structure comprising in combination a flexible, substantially air-impermeable, vibratile membrane, resonant over a wide range of frequencies and exposed on its forward surface to the sound to be absorbed, and a sound absorbing element disposed behind and adjacent to the said membrane, the said membrane having a mass of approximately 22 grams to the square foot when the sound to be absorbed is of a fre-

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quency of the order of 1,000 cycles and having a mass of approximately 230 grams to the square foot when the sound to be absorbed is of a frequency of the order of 300 cycles.

7. A structure for absorbing sound of a given frequency range, comprising a base member and a second member exposed to the sound and of predetermined mass spaced from said first named member at a predetermined distance, the given frequency (f), the said mass (m), and the predetermined distance (s) being proportioned so that $f(sm)^{\frac{1}{4}}$ is equal to approximately 780 when (f) is approximately the mean frequency of the range and is expressed in cycles per second, (s) in inches, and (m) in ounces per square foot of the exposed member.

8. A sound absorbing structure effective over a predetermined range of sound frequencies comprising a base member capable of reflecting sound waves, and a member formed of a material which enables it to be appreciably vibrated by impinging sound waves spaced from said base member, the magnitude of the spacing being approximately ¾ inch and the mass of the vibratile member varying between 22 to 230 grams per square foot when the frequencies at which the structure is to be effective vary between 1,000 and 300 cycles per second.

9. A structure for absorbing sound of a given frequency range comprising a base member and a membrane exposed to the sound and of a predetermined mass and spaced from said base member at a predetermined distance, the relationships between the spacing (s), mass (m), and frequency (f) existing in an order which is represented by the following table:

(s)	(m)	(f)
In inches	In grams/sq.ft.	Cycles/sec.
¼	690	300
¼	66	1000
½	345	300
½	33	1000
¾	230	300
¾	22	1000

10. A sound absorbing structure comprising a base member and a second member exposed to the sound and spaced from the first named member at a predetermined distance, the second member being formed of rag felt partially saturated with asphalt so as to be appreciably vibrated by impinging sound waves but capable of absorbing that portion of the air-borne sound which does pass into the member.

11. A sound absorbing structure comprising a substantially air-impermeable base member, and a flexible, substantially air-impermeable, vibratile membrane, resonant over a wide range of frequencies and having a sufficiently high internal resistance to rapidly damp out free vibrations resulting from displacement caused by impingement of a sound wave thereupon, said membrane being exposed on its face to the sound to be absorbed and spaced from said base member.

JOHN S. PARKINSON.

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